

The CDM maze

issues and options

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Issues and options for implementing CDM projects

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Introduction

The CDM (clean development mechanism), introduced in the Kyoto Protocol to the FCCC (Framework Convention on Climate Change), has been conceived as an international instrument to promote sustainable development in the developing countries along with cost-effective climate change mitigation. The idea is to facilitate co-operative projects between developed and developing countries for reduction of GHG (greenhouse gas) emissions (primarily CO₂ [carbon dioxide]), with the opportunity for additional financial and/or technological inputs from the developed countries towards cost-effective emission reduction from the developing countries.

The CDM brings together the need for Annex 1 countries to initiate investments in carbon emissions reductions, with the availability of low-cost carbon emissions reductions opportunities in non-Annex 1 countries. Through the process, enterprises in Annex 1 countries can, in partnership with enterprises in the developing countries, invest in establishing state-of-the-art technologies in host developing countries. The lower technological baseline in the developing countries implies that such investments would result in greater potential reductions in carbon emissions than similar investment in the Annex 1 country. In return for this investment, the Annex 1 country enterprise would seek returns in the form of a stream of carbon emissions reductions (as compared baseline). This CDM process would thus be a more cost-effective mechanism for mitigating climate change than if the Annex 1 country enterprise had to implement an equivalent reduction at home. At the same time, the process would also direct rapid transfer of cutting-edge, climate-friendly technologies to the developing countries. The process, however, will have to address the commercial risks associated with the introduction of new technologies through financial/technology flows

from Annex 1 countries. The process will also manage operation risks resulting from the need to prove additional and sustainable reductions in carbon emissions over the project lifetime.

However, a number of prerequisites are required in order to exploit the benefits from the CDM process that the developing countries hope for. Two aspects are of particular interest in this regard. Firstly, it would be in the interest of developing countries to initiate the establishment of processes and procedures to start and absorb CDM activities. This would require a significant CDM capacity to be built up, both in government and in enterprises, with a substantial up-front investment. The absorption of the advanced technologies facilitated by the CDM process requires host country enterprises in developing countries to be competitive and growing, in order to be attractive business partners for investments from Annex 1 countries. If data requirements for baseline setting put additional barriers, these could severely limit the number of enterprises within a host (developing) country that can participate in the CDM process. In other words, the CDM process could actually lead to an increase in inequity within the host country rather than help bridge existing disparities in environmental performance of enterprises. Furthermore, the transfer of CERs (certified emission reductions) and the Annex-1 country investment in CDM projects requires both facilitation and negotiation. Human and institutional capacity development to enable this negotiation is, therefore, a pre-requisite.

Secondly, CDM projects must address the sustainable development aspects of developing countries, criteria of which have to be clearly defined by the governments of developing countries. The attractiveness of CDM for host countries lies in its possibility to support the developmental process, and not in the occurrence of a few advanced-technology projects alone. Therefore, it is essential to ensure high developmental spillover from CDM projects to the design of these projects.

The above discussions suggest that a comprehensive framework is required to facilitate implementation of the CDM projects by taking care of the host country's specific developmental needs. In order to develop a set of rules for operationalizing CDM in this context, a bottom-up approach has been adopted to identify guidelines that could be useful

in developing a comprehensive framework and evolving clear policy messages that are needed to facilitate implementation of the CDM projects. This involved the examination of five case studies. These cases were chosen to reflect the major sectors within which CDM projects could occur and illustrate several complex issues that arise in the assessment of additionality, establishment of baselines, and implications on sustainable development. All case study partners have been participating in technology transfer projects implemented under the energy and development programme of the Swiss Agency for Development and Cooperation.

Technology transfer issues discussed below are based on practical experiences in dealing with barriers, in making investment in environmentally sound technologies an attractive business case.

Case studies 1 and 2 examine HFC (hydrofluorocarbon) abatement in the domestic and commercial refrigeration sector, where additionality is based on the Montreal Protocol requirement to phase-out CFC-based (chlorofluorocarbon) technologies. HFCs, which were promoted as substitutes for CFCs and other ODS (ozone depleting substances) before the Kyoto Protocol, were declared part of a group of six GHGs whose emissions have to be controlled in the subsequent negotiations. This has led to a need to integrate the environmental objectives of both protocols. The differences between the two protocols on substances to be phased out or controlled necessitate examining the inter-linkages between the two for cogent policy-making and closer co-operation between the two treaty regimes. Case study 3 investigates the synergies between refrigerant technology change and investment in improved energy-efficiency. This case combines the conversion from HFC-134a to isobutane with energy-efficiency improvements in the designs of domestic refrigerators, and thus, investigates a typical demand-side CDM case. The case illustrates a possible approach to baseline setting in projects, which aim at improving the energy efficiency of home appliances. Demand-side measures to curb the growth of power consumption are considered an important contribution to sustainable development, considering the size of transmission losses, which hover around 30% in the Indian grid.

Case study 4 examines a technology modernization project in a small-scale iron foundry cluster and advanced

cogeneration project in sugar mills is examined in case study 5. Both these cases highlight the need for a sector approach and elaborate on issues that are necessary to be considered for developing CDM rules. The foundry project would utilize CDM funds to establish delivery chains for credit and technology to the small-scale units, thereby, enabling the introduction of a new technology with a matching pollution control system. The cogeneration project will utilize the funds for removal of the barriers, and create markets for advancement of the technology. Both projects aim to increase the environmental integrity, decrease transaction costs to users, and thus, increase the financial attractiveness of the energy-efficient and environmentally sound technologies for wider adoption at the sector level.

HFC abatement in the refrigeration sector

Interdependencies between the Kyoto Protocol and the Montreal Protocol

The Kyoto Protocol addresses the issues of global warming and climate change and specifies a set of six GHGs for which Annex 1 countries have to achieve a weighted reduction of 5.2% by 2008–2012 as compared to the 1990 emission levels. The set of six GHGs consists of three gases which are covered under UNFCCC (CO₂, N₂O, CH₄) and three technical gases with a high specific GWP (global warming potential). Under the Kyoto Protocol, non-Annex 1 countries have no quantified emission limitation and reduction commitments. The Kyoto Protocol has also introduced three flexible mechanisms of which the CDM aims to promote sustainable development along with cost-effective GHG abatement in developing countries.

The Montreal Protocol, on the other hand, was established to control and phase out the use of ODS within a prescribed time-frame, which is different for developed and developing countries. To cope with the burden of incremental cost of the ODS phase-out, the Multilateral Fund was established under the Montreal Protocol to aid the transfer of technology between developed and developing countries. The effectiveness of this technology transfer is vital for the developing countries to comply with the control measures of the Protocol. The Montreal Protocol specifies and controls the use of gases

on the basis of their ODP (ozone depleting potential) only, and does not take into consideration the GWP of ODS substitutes, such as HCFCs (hydrochlorofluorocarbons) or HFCs. Gases with a high ODP such as CFCs are to be phased out early while, gases with a low ODP such as the HCFCs are allowed for use for an extended period. Developing countries have agreed to freeze consumption levels of HCFCs only by year 2016.

In the developing countries, the ozone depleting CFCs in the refrigeration and foam sector are currently in the process of being replaced by HCFCs and HFCs as the emission levels frozen by 1999 have to be reduced to 50% by 2005 and completely phased out by 2010. These phase-out processes of ODS under the Montreal Protocol now overlap with the first commitment period of the Kyoto Protocol. As HFCs play an important role as substitutes to CFCs and HCFCs in the refrigeration and foam sector, the concern of the developing countries is that in a transition technology by opting for HFCs now. With the Kyoto Protocol in force, investment in technology development in industrial countries will be directed into alternatives with low GWP where such options are available, and transfer these GWP technologies to developing countries as alternatives to new investments into HFCs.

Rationale of the case studies in domestic and commercial refrigeration

For phasing out the use of CFC-12 as a refrigerant in domestic refrigerators, there are two technologies competing in the global market: HFC-134a and isobutane (R600a). HFC-134a is a GHG with a GWP value of 1300, whereas the GWP of isobutane is negligible at 4. The HC (hydrocarbon) technology based on isobutane was developed in Germany and leads the energy-efficient models in the European market. It has penetrated into China and is considered as a technology option also by Japanese manufacturers, since inclusion of HFCs as a GHG in the Kyoto Protocol. The Multilateral Fund of the Montreal Protocol has supported a number of conversion projects in the domestic refrigerator sector in developing countries, of which the majority is based on HFC-134a technology. One of the barriers acting against market penetration of isobutane is the higher capital cost of

conversion to take care of its flammability. These costs are only partly funded by the Multilateral Fund of the Montreal Protocol. A second barrier is the availability of HC refrigerant and other components, which are economical to supply only if a critical mass of demand exists within a country. HFC-134a is used in many other refrigeration applications and is much in demand in most developing countries. As in several Annex 1 countries, HFC emission control measures are under evaluation, and it is viable to opt for HFC alternatives with low GWP where available at comparatively low incremental cost. Isobutane technology in domestic refrigeration is such an alternative – in particular since it also offers the potential to improve the energy-efficiency of domestic refrigeration appliances.

For an imaginary CDM project with a specific lifetime 2003–2012, the popular Indian 165-litre refrigerator model was examined for a manufacturer entering into collaboration with an Annex 1 HC technology partner. The annual sales of all smaller refrigerators with basically the same refrigeration system is assumed to be 800 000 units in 2003. Energy-efficiency improvement measures implemented in the refrigerator design along with the refrigerant conversion to isobutane were also investigated as an additional investment option (case study 3).

A second case study is built on conversion of the foam-blowing agent and the refrigerant from HFCs to low-GHG technologies in the small-scale commercial refrigeration industry (case study 2). In this sub-sector, HCFC-141B is the dominating foam-blowing agent presently used in developing countries. Control schedule under the Montreal Protocol phases out the production of HCFC-141B in the US and other industrialized countries by 2003. Substitutes to follow are HFC-134a or HFC-245fa. Both HFC alternatives will be available in India through import only, while HCFC-141B would have to be produced in a developing country for a transition period until phase-out of HCFCs enters into force also in developing countries. The investigated case study assesses a direct conversion from HCFC-141B to cyclopentane as a low GHG technology under CDM from 2003 onwards. Cyclopentane is used by larger domestic refrigerator manufacturers in developing countries, where the Multilateral Fund of the Montreal Protocol subsidizes the additional safety cost. This facility had not been established

under the Multilateral Fund in the small-scale commercial industry for cost-effectiveness considerations. The case study demonstrates that at CER trade prices around 15 dollars per TCE (tonne of carbon equivalent) the conversion is economically viable also for small-scale manufacturers producing about of 30 000 units per year. The refrigerant used in deep freezers and bottle coolers produced by small-scale commercial manufacturers is converted from HFC-134a to a mixture of propane (R290) and isobutane (R600a).

Additionality and baseline

To qualify under the CDM, projects have to demonstrate that the GHG emission reductions claimed are *in addition to any that would occur in the absence of the certified project activity*.

Determining additionality in HFC abatement projects is complicated by the ongoing process of ODS phase-out under the requirements of the Montreal Protocol. Indian refrigeration equipment manufacturers are required to phase out the use of CFCs by end of 2002. Most manufacturers in India have decided to convert to HFC-134a, and some are considering the HC technology option as new refrigerant. Under these circumstances, does the adoption of isobutane technology by a CFC-12 manufacturer in 2002 constitute a CDM project based on HFC abatement? Does a manufacturer have to use HFC-134a to qualify for its abatement? The dilemma arises since CFCs (with high ODP and high GWP) are controlled substances under the Montreal Protocol and are, therefore, not considered as GHGs under the Kyoto Protocol. Economically it makes sense to encourage a one-step conversion from CFCs into a low GHG technology such as isobutane. CDM rules should, therefore, encourage one-step conversions to environmentally sound technologies during the ongoing ODS phase-out process under the Montreal Protocol. CDM could also take care of financing the incremental cost of GHG abatement, which the Multilateral Fund is not prepared to subsidize.

The same dilemma is also described by the second case study on conversion from HCFC-141B to cyclopentane as a foam-blowing agent. As mastering a new technology demands investments, it makes economic sense to avoid the use of HFCs as HCFC substitutes and convert directly from HCFC-141B to cyclopentane. HCFCs are controlled under

the Montreal Protocol with a complete phase-out in developing countries by 2040. As there are two or more HFC alternatives presently evaluated as substitutes to HCFC-141B, the issue arises as to the basis on which enterprises shall prepare baselines, if they are not currently using an HFC alternative. In both case studies investigated, HFC-134a has been chosen as the chemical that would be adopted in the absence of certified project activity. This chemical and the technology for its use is available at commercial terms in the international market. The quantities of HFC-134a use per unit of production as refrigerant or as foam-blowing agent have also been established through user-experience.

Contribution to sustainable development

From an economic perspective of technology transfer, the investigated HFC abatement projects offer significant gains for developing countries in addition to GHG abatement. The Montreal Protocol and the Kyoto Protocol put pressure on the economic viability of both HCFC and HFC-based technologies. There is, therefore, a certain risk of dumping such technologies on developing countries. If through CDM, conversion to HCFC and HFC alternatives can be accelerated in developing countries, consumers stand to benefit at early stages from price effects because of the mass-scale use of environmentally sound low GHG technologies. Market forces will then check the risk of dumping of technologies, which may become obsolete after a decade or two. As consumer durables remain in use for longer time in developing countries, frequent changes in technologies put a strain on consumers as the investment in service network, which is often in the hand of the informal sector, increases. In the near future, measures to recover and recycle HFCs may work in segments of the refrigeration sector in industrialized countries and the cost of such measures would hardly be accepted by the consumer in developing countries. Barriers to establishing HFC recovery and recycling schemes in developing countries are significant.

Mechanism rules

Practical and credible rules for CDM are imperative for the success of the Kyoto Protocol and to mitigate the adverse effects of climate change. These rules are still being negotiated, taking into account various concerns and issues that

arise from assessment of country-based priorities. For developing countries, CDM may bring in unique opportunities as it may lead to development-related advanced technology transfer. There are, however, many issues that have to be addressed to ensure their effective participation in the mechanism. Some of the major issues include the following.

- The emerging option, that sector benchmarks may have to be followed, has considerable implications on baseline rules, in terms of its credibility and applicability. The concern lies in poor data availability prevailing in the developing countries at project level. Generating reliable databases for sector benchmarks would entail substantial time and cost. If the first movers in CDM have to bear the cost of establishing credible sector benchmarks, the transaction cost may grow to prohibitive levels. The credibility and applicability of a sector baseline would also be low, due to the large number and varied performance levels of the enterprises within an intervening sector operating in large countries with significant regional differences.
- Country priorities, in terms of resources at its disposal, would influence the choice of a baseline pertaining to a potential CDM project. The large domestic availability of coal in India may tilt the scale in favour of establishing sector benchmark based on carbon intensity of the grid average. The emission intensity in a country with a coal-based power sector such as India and China would be in sharp contrast with countries having substantial hydro capacities in their grid average (e.g. Brazil). Uniform international acceptability of baseline rule based on capacity addition or grid average, therefore, raises a concern for developing CDM rules. Technology applicable for India and China would be irrelevant for Brazil.
- There is a trade-off between the goals of environmental integrity and the transaction costs in the baseline establishment process. The need to optimize costs in developing countries may lead to a compromise leading to a less-than-ideal environmental integrity. The rules for this compromise need to be developed.
- The capabilities required to absorb the advanced technologies facilitated by the CDM process severely restrict the number of enterprises within a developing country that can participate in the CDM process. The smaller and

relatively inefficient enterprises are not likely to benefit from the CDM process, as higher sector baselines as well as transaction costs would act as a disincentive for them to participate. From the point of view of sustainable development, it would be in the interest of developing countries to support the CDM rules to provide a level playing field, and thus, promote equity among potential participants.

Rationale of the case studies

In order to advance understandings on these complex issues, a bottom-up case study simulation has been undertaken. These case studies display strong and clear rationale towards sustainable development that developing countries strive for. These relate to the aspects of economic, social, and environmental sustainability, and include issues like decentralized industrialization, generation of large employment opportunities, participation of weaker section of society in the development process, high interface with local communities, enhancing resource-use efficiency, local environmental improvement, etc. Since aspiration from the CDM is to facilitate transfer of such development-linked advanced technologies, the existing technological base in the developing countries needs to be upgraded. The rationale, therefore, lies in the need to develop appropriate CDM rules that promote technologies for sustainable development. Each of the case studies discusses several such aspects, bringing out clear policy messages for framing appropriate CDM rules in this context.

Small-scale foundry sector

Despite the prominence of SSIs (small-scale industries) constitute in the Indian economy, technological change in the sector has been extremely limited. The manufacturing processes are highly energy consuming and polluting. This is primarily because the small size of enterprises increases transaction costs of developing new technological products. Lack of adequate information, indigenous capability, availability of finance and skilled manpower, besides a host of social problems further make the cleaner technological interventions in SSIs both costly and difficult. Due to this stagnation, the sector faces twin threats of decreasing competitiveness and enhanced environmental enforcement action. Implementation of environmental strategies in SSIs needs a specific context,

different from that of large-scale industries, so that the decision makers can cope with the sector's special needs.

The case study addresses the upgradation of a cluster of small-scale foundry units located in Howrah, near Calcutta, in India. The project seeks to upgrade the technology in a sector where it is not happening on its own. This type of CDM project would enjoy the advantage of higher productivity in established markets and would be sustainable once the initial transaction and learning (risk management) costs are overcome. The CDM project would piggyback on a commercial credit line, and CDM funds would finance the establishment of a delivery mechanism and an interest buy-down to raise the return on investment to an acceptable level.

Cogeneration in sugar mills

The sugar industry in India today enjoys critical economic status, due to national and international market and policy framework. This has resulted in their limited access to resources and capabilities. Their energy needs have increased over the years due to expansion and diversification. They offer excellent potential for modernization and energy-efficiency improvement. Sugar mills cogenerate steam and power for their own requirements by burning renewable fuel generated in the process, i.e. mill bagasse. The technology configurations for this captive cogeneration are still inefficient, leading to inefficient utilization of the renewable fuel, bagasse. Despite the sector having an enormous potential of generating exportable surplus from such projects, the actual realization has been low due to borderline economic viability of these projects and complex barriers related to technology, finance, policy, regulation, and development.

The CDM project would envisage to reduce the dependence of existing power generation through thermal route, thus reducing CO₂ emissions. This activity also addresses non-CO₂ concerns such as enhancement of the local air quality, improving the availability, quality, and reliability of the grid power, improved socio-economic status of rural populace around, and therefore, necessitates negotiation to assess the direct costs of GHG reduction measures alone. The CDM funds would be utilized to remove market barriers, and thus, create markets for advancement of the cogeneration technology with extra high-pressure configuration.

Baseline rules

In keeping with the philosophy and the language of Article 12, the determination of the achieved emission reductions requires the specification of a baseline to which reductions would be additional. Methods and modalities for setting baselines are still open for interpretation and decisions by the Parties. Article 12 does suggest a project-specific approach for baseline development, as they are likely to be more environmentally sound at the project level. However, they may result in substantially higher transaction costs and are not free from fears of 'gaming'. Benchmark-oriented baselines, on the other hand, are normative in essence and likely to be less accurate at the project level. They would reflect actual reductions on average. The development of standard-oriented baselines would reduce the transaction costs for all market participants and promote CDM activities. These decisions are expected to be reached as a result of ongoing negotiations.

Rule 1. Sector baselines cannot be implemented until sufficient data are available

The case studies suggest that poor data availability in developing countries makes it difficult to implement sector baselines. Large number of enterprises operating within a sector further lowers the credibility, and hence applicability, due to the heterogeneity in their performance levels.

The point is illustrated by the case of the Howrah foundry cluster. The cluster houses about 350 foundry units with varied vintage, size of operations, operating practices, and end products. These units typically operate on batch process to adjust the fluctuations in market demand of products and availability of the raw materials. Therefore, the capacity utilization of these units is low and varies throughout the year. As a result, despite using similar base technology their performance level differs widely. Typical of small-scale operations, the data measurement, monitoring, and record-keeping practices in the cluster are practically unseen and lack any scientific method of ascertaining quantities of inputs and outputs consumed/produced per operation. Under these circumstances, how is a baseline to be evolved? A baseline on project-to-project basis would involve significant cost, as

individual units would have to be audited. A standard baseline on sector average would also not be very practical due to heterogeneity of operations. International baselines (such as Organization for Economic Cooperation and Development average) are also not valid due to differences in fuel type and operation size. Proper evolution of any baseline would require a significant up-front investment in creating a proper system of data generation as well as in generation of certain critical data beforehand. Without this up-front investment, the credibility of any baseline would be low.

Rule 2. Choice of baseline type would be influenced by country resources

Another important criterion that influences the choice of a baseline is the host country's priority in terms of resources at its disposal. The case of sugar mill cogeneration demonstrates this aspect. India has large availability of coal. In the power generation CDM projects, the key question is, should carbon intensities of the 'grid average' or 'capacity addition' on fossil fuel side (a mix of modern coal and combined cycle gas plants) become sector benchmarks? Due to large domestic availability, the Indian grid average is made up largely of coal. The benchmark based on grid average would make the projects more attractive due to large potential CO₂ emissions reduction. On the other hand, capacity addition will deprive existing coal power plants of any benefits the CDM may bring to them.

Another related aspect of this is if capacity addition as sector benchmark is chosen, who defines the set of projects in sectors with strong political influence such as power sector? Do all countries agree that capacity addition benchmarks deprive existing coal power plants of the benefits CDM may bring them? India and China are both large GHG emitters. If India agrees to this argument, then does China also support the same? Is it acceptable to have different rules in different countries, for example, sector-based baselines in India (due to large percentage of coal in grid average) and project-based baseline in Brazil (due to large percentage of hydro in grid average)? The uniform international acceptability of these issues is yet another factor that the CDM rules must consider.

Rule 3. Trade-off between environmental integrity and transaction costs

There appears to be a trade-off between the desired environmental integrity level and the associated transaction costs in establishing the baselines. The optimization of transaction costs in the baseline establishment process may sometimes lead to less-than-ideal environmental integrity. This compromise can be assessed on a project basis alone. The rules for this compromise need to be developed.

The case study on small-scale foundry cluster amply demonstrates this aspect. The existing small-scale operations in India are highly energy-consuming and polluting in nature. They invariably use coal as a fuel due to its large and easy availability and comparatively lower cost. In these operations, there are no off-the-shelf technological solutions available to reduce energy intensiveness and process-related emissions. With new stringent environmental rules, these industries are finding it increasingly difficult to cope with the existing situation. However, they continue to operate as before, as technological choices are either not clear or not within the financial reach of the entrepreneurs. The CDM project seeks to implement a technology modernization option with long-term environmental benefits. The direct benefits of the project include reduced CO₂ emissions (from 523.4 to 336.3 thousand tonnes a year), resource conservation (improved furnace efficiency – coke to melt ratio improves from 18% to 9.2%), and improvement of local air quality (lower SPM [suspended particulate matter] emissions – from 557 to 53 mg/Nm³) much below the prevailing standards. The indirect benefits include the prevention of loss of jobs (due to threat of closure) and dislocation of workers (direct employment in the cluster is 0.5 million, indirect employment is estimated to be 1.0–1.5 million). The desire to achieve higher environmental integrity would require substantial funds to be invested in establishing the baseline, which are estimated to the tune of 22 million dollars and setting up a mechanism to measure and monitor abated CO₂ emission. Once the desired higher environmental integrity is established, development and deployment of a suitable technology package would require further funding estimated at 28.6 million dollars.

Sustainable development rules

Sector benchmarks may adversely affect the sustainable development objectives of developing countries

The attractiveness of CDM for host countries lies in its possibility to support the developmental process, and not in the occurrence of a few advanced-technology projects alone. The current discussion about the nature and scope of CDM projects reflects a bias towards large industrial or energy sector interventions. The absorption of the advanced technologies facilitated by the CDM process requires host country enterprises to be competitive and growing. This severely limits the number of enterprises within a developing country that can participate in the CDM process. Industrialized countries have introduced eco-labelling schemes for home appliances only in the last decade. Similar efforts are on in many developing countries but as regulations needed are complex, the systems are not in place yet. Accordingly, few have appliances with independent and certified data on energy consumption are presently available in developing countries. CDM rules should encourage early enterprises to improve the energy-efficiency of their products and not hold back an entire sector until cross sector data has become available – a process that may take another decade and needs to be supported by public resources.

The smaller and relatively inefficient enterprises from the small-scale sector (foundries, bricks) are not likely to benefit from the CDM process, as harmonized sector baselines would act as a disincentive for them to participate. These enterprises would have to undertake a significant up-front investment to improve their performance level at par with the efficient enterprises. From the point of view of sustainable development, it would be in the interest of developing countries to support the CDM rules to provide a level playing field, and thus, promote equity among the potential participants.

The small-scale iron foundry cluster is a case in point. The Government of India has a deliberate policy to support development and sustained growth of small-scale enterprises due to a host of socio-economic reasons. As these enterprises often have a low awareness and no investment potential, their

performance levels are typically low and efforts to bring about a technological change are both costly and difficult. The fixation of a sector baseline would mean lower carbon credits from such projects unless a significant up-front investment is made to improve their base performance. This limits the scope of their participation in an international mechanism like CDM and, therefore, would be against the sustainable development objectives of the developing countries.

Conclusion

The paper highlights several issues that are worth considering while the rules of CDM are being negotiated. The case studies on HFC abatement calls for an integrated approach taking into consideration enterprises in developing countries are investing in CFC-free technology now. Technological options exist that comply with the demands of both the Montreal and Kyoto protocols allowing developing country enterprises to avoid the need to change technology twice within a short time span. It is important at this stage to make the rules flexible with due considerations to the decision-making process of the industry. It is highly unlikely that industries, which have switched over to HFCs as per the requirements of the Montreal Protocol once, will soon be able to make further investments on their own in other technological options as per the requirements of the Kyoto Protocol. An early integration of the two protocols would avoid the two-step conversion of plant facilities. Initial CDM project to avoid the use of HFCs would immensely benefit the industry and consumers by providing access to more efficient technological choices and funds. CDM funds could be utilized to finance the incremental cost of these choices not covered under the Montreal Protocol.

The other case studies represent the sectors where technological upgradation is not happening on its own. Suitable CDM interventions could contribute to removing barriers and create markets as well as institutions to facilitate implementation of the projects as per requirements. Significant amount of funding would be required to be invested up-front to facilitate these market transformations. On the policy side, these case studies illustrate that the type of projects, intervening sector, and country priorities would largely influence the choices of baselines for a CDM project. The potential CDM

projects must also qualify towards host country's specific priorities by showing strong links towards sustainable development. Unless the projects clearly demonstrate this aspect, there would be little incentive on the part of developing countries to participate in the mechanism. There may be other instruments, besides CDM and capacity-building, to create the level playing field that allows developing countries to achieve sustainable development. In a bid to optimize the high transaction cost by simplifying CDM rules, targets of achieving higher environmental integrity and sustainable development may get compromised. CDM rules must take these aspects into consideration to be acceptable to developing countries.

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Introduction

This study aims to develop a simulation case study on HC technology for domestic refrigerators under the CDM of the Kyoto Protocol. A model has been developed to estimate the TCE abated due to the use of HC-600a instead of HFC-134a as the refrigerant and cyclopentane instead of HCFC-141b/HFC-134a/HFC-245fa as the foam-blowing agent in Indian domestic refrigerators. The study also looks at the possible integration of the Montreal and Kyoto protocols for developing countries in order to progress towards the goals of both protocols simultaneously.

The Montreal and Kyoto protocols

The Montreal Protocol on substances that deplete the ozone layer was established to phase out the use of ODS within a prescribed time-frame. The Multilateral Fund of the Montreal Protocol was established to aid the transfer of technology between developed and developing countries in order to comply with the control measures of the Protocol. The Montreal Protocol addresses gases that are only ozone depleting and does not take the GWP into consideration. The Kyoto Protocol, which addresses the issues of global warming and climate change, was established to abate the use of GHG. Under the Kyoto Protocol, when ratified, it is obligatory for Annex 1 countries to make GHG reduction commitments while non-Annex 1 countries have no such commitments. The Kyoto Protocol introduced three flexible mechanisms, namely joint implementation, emissions trading, and the CDM to promote GHG abatement.

Integration between Montreal Protocol and Kyoto Protocol

The Kyoto Protocol has added a fresh dimension to the adoption of new technologies while phasing out CFCs, under

the Montreal Protocol. To comply with both the protocols, the technology should be both ODS-free, i.e. use gases that have zero ODP (ozone depletion potential) and also lead to GHG abatement. Environmentally sound technologies under the Montreal Protocol are interpreted only to mean those technologies that are not damaging to the ozone layer without any consideration to the global warming factor. It is clear that both the Montreal Protocol and Kyoto Protocol are inter-related as one of the alternative solutions for Montreal Protocol, i.e. HFC, is an obstacle under the Kyoto Protocol (as HFCs, being GHGs, are under regulation). This has necessitated the possible integration of the Montreal Protocol and Kyoto Protocol.

Refrigerators use the two ODS, CFC-12 as a refrigerant and CFC-11 as the blowing agent in the PUF rigid foam. HFCs were the first of non-ODS developed. HFCs have many thermodynamic properties similar to CFCs and these were considered to be ideal alternative candidates. HFCs are, however, one of the GHGs to be regulated under the Kyoto Protocol and hence developing countries are concerned about the future of HFCs under the Kyoto Protocol. The adoption of HFC technology as the CFC replacement could lead to a multiple conversion due to their possible non-availability or control later. There is no financial mechanism for such subsequent conversions.

Hydrocarbon technology under clean development mechanism

Another alternative to CFCs are HCs for they have zero ODP and negligible GWP. It is also a long-term solution since the future of HFCs and HCFCs is uncertain within the first commitment period. The only major issue with the HC technology is the safety aspect due to flammability of HCs. The HC technology is well established and has been successfully adopted by many European countries whereas most enterprises in developing countries are hesitant to adopt this technology as the grant from the Multilateral Fund is not adequate to cover the safety aspects. Therefore, it is only rational to consider HC technology, by integrating both Montreal Protocol and Kyoto Protocol with a partial grant from Multilateral Fund and additional incentive through the CDM.

This case study aims to develop a CDM for HC technology for domestic refrigerators. It considers the use of

HC-600a as a replacement for HFC-134a refrigerant and cyclopentane as a replacement for HCFC-141b/HFC-134a/HFC-245fa foam-blowing agents. Equivalent carbon offset has been estimated. Additionality and sustainability criteria have been established.

Baselines

The refrigerator industry in India still largely uses CFC-12 as the refrigerant and CFC-11/HCFC-141b as the foam-blowing agent. However, according to the Government of India Draft regulation, CFCs must be phased out by 2003 in all new productions. It is expected that by 2003 a majority of Indian refrigerator manufacturers will have opted for HFC-134a as the refrigerant and foam-blowing agent and a few may have converted to HC technology. Therefore, for the estimation of TCE abated, HFC-134a is considered as the baseline and hence, TCE abatement is estimated as GHG abated by the avoidance of HFC-134a as the refrigerant and the foam-blowing agent.

Production

Production of domestic refrigerators by a model enterprise is assumed to be 0.8 million units of 165-litre direct cooled refrigerators in 2003 with an annual growth rate of 15%.

Project life

Project life is considered from 2003 to 2012 although the refrigerators may continue to be in service well beyond 2012. It is assumed that the production of HC refrigerators commences from 2003 as per stipulated regulations. The end of the first commitment period for Annex 1 countries is 2012 and hence this marks the end of the project life.

Refrigerant charge

Refrigerant charge varies from 95 g to 105 g for CFC-12 for Indian domestic refrigerators. For this study, a refrigerant charge of 100 g has been assumed for CFC-12 and 95 g and 40 g for HFC-134a and HC-600a, respectively.

Blowing agent requirement

For CFC-11/HFC-134a/HCFC-141b, a consumption of 600 g of blowing agent has been assumed.

Factory loss

During production, the losses assumed are 20 g of refrigerant per unit and 30 g of foam-blowing agent per unit.

Recharging and recovery

Recharging and recovery have not been considered for this case study. Recovery of refrigerant or blowing agent is not yet practised in India.

Power consumption

Power consumption varies from 0.75 to 1.5 kWh per day. The limit set by IS 1476, under revision, is 1.25 kWh per day for a refrigerator capacity in the range 66–165 litre. In this case study, a power consumption of 1.1 kWh per day is assumed, although a majority has daily power consumption well above this value.

Energy-efficiency

A three per cent increase in energy-efficiency is assumed for the conversion of refrigerant from HFC-134a to HC-600a as the HC-600a compressors are claimed to be more energy-efficient. A 10% decrease in energy-efficiency is assumed for the conversion of foam-blowing agent from HCFC-141b to cyclopentane while a 2% increase in energy-efficiency is assumed for the conversion of foam-blowing agent from HFC-134a to cyclopentane.

Equivalent carbon offset

Although the bases for determination of credit value of the equivalent carbon offset and cost-effectiveness are not well established, the carbon credit is worked out based on the assumption that an international carbon credit market will emerge from 2001 onwards. The assumed cost is 14.66 dollars/TCE abated and this is depreciated at a discounting rate of eight per cent.

National CO₂ emission factor

The emission factor for the power production mix in India is estimated as 1.16 kg CO₂/kWh. This includes 30% transmission losses.

Additionality

The CDM simulation case study for HC refrigerators satisfies the issue of additionality on the following points.

Investment additionality

The initial capital investment required for the adoption of HC technology is higher due to the additional safety features. The Multilateral Fund does not support the full cost of conversion, if the conversion is directly from CFC-12 to HC-600a. The Multilateral Fund will also not support the changeover from HFC-134a to HC technology. Hence, there is need for an additional investment to support the project. The HC technology thus fulfils the investment/financial additionality criterion, since it would not be possible to implement otherwise.

Technological additionality

As HC technology is the latest and best available environmentally sound technology, it also fulfils the technological additionality criterion.

Sustainability

The HC technology for domestic refrigerators fulfils the sustainability criteria on the following grounds.

Economic sustainability

The HC technology can use indigenous resources (HC refrigerant, mineral oil, etc.) with minimum import. Thus, it leads to self-reliance and results in saving of foreign exchange and reduction in product cost.

Environmental sustainability

Environmental benefits include the phase-out of ODS, namely HCFC-141b and the abatement of GHG, namely HFC-134a simultaneously. This is expected to benefit the ecology immensely.

Technical sustainability

There are very few changes in the manufacturing process of the appliances and there are also no major IPR (intellectual property rights) issues involved.

Social sustainability

The HFC-134a technology requires a lot of training and additional investment for the service sector, posing a threat to this sector. However, HC-600a technology does not pose any problem nor is there disruption of employment opportunities in the service sector.

Monitoring and verification

Currently there is no need to declare the energy-efficiency of refrigerators by the manufacturers. The tests are made by manufacturers in their own laboratories. Therefore, it is necessary to establish an accredited national test facility for testing refrigerator energy-efficiency as per Indian standards / International standards, as the case may be. A competent and independent third-party entity should track the project performance and verify the data on actual project emissions to determine the quantity of emission reduction achieved, based on the standards specified by the Conference of Parties / Meeting of Parties. These verifiers might be the same who assessed the project proposal in the beginning.

Results and discussions

The study is performed to use HC-600a in place of HFC-134a for the phase-out of CFC-12. Similarly for the foam-blowing agent, the study is performed on the use of cyclopentane for the phase-out of HCFC-141b. Hence, the baseline is HFC-134a both for refrigerant as well as for foam-blowing.

Table 1 shows the estimated CER generated. It also shows the equivalent CO₂ abated.

The study reveals that the total CERs generated due to the abatement of HFC-134a as the refrigerant is 7.96 million dollars for the period 2003–2012. Similarly for foam, the total CERs generated due to the abatement of HFC-134a as the foam-blowing agent is 33.10 million dollars. By adopting HC technology, the manufacturers can avoid the possible double conversion and may derive the benefits.

Conclusion

If the Indian refrigerator enterprises were to adopt HFC technology, then in the long run they may face uncertainties

Table 1 Greenhouse gas abatement and CERs generated due to conversion of refrigerant and foam-blowing agent

Technology	Total equivalent CO ₂ abated (MTCE)	Estimated value of CERs (in million dollars)
Refrigerant		
HFC-134a	0.88	7.96
Foams		
HCFC-141b	1.10	—
HFC-134a	3.79	33.10

CO₂ – carbon dioxide; MTCE – million tonnes carbon equivalent; CER – certified emissions reductions

with availability and acceptance of HFCs. There may be a possible second conversion to HC technology later. The HC technology requires stringent safety measures, as HCs are flammable. This results in additional safety costs thus leading to constraints in its adoption. There is also no major IPR issue for the HC technology. This CDM simulation case study for Indian domestic refrigerators reveals that the project fulfils all the criteria for CDM of Kyoto Protocol such as additionality, sustainability, and cost-effectiveness. It is possible to abate ODS and simultaneously generate significant CERs. Therefore, there is a need to integrate Montreal Protocol and Kyoto Protocol for such cases.

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Scope

The objective of this study is to develop a simulation case study based on non-GHG technologies for commercial refrigeration under CDM of the Kyoto Protocol. A model has been developed to estimate the CER due to change over from HFC-based technologies to HC technologies both for foam-blowing as well as for refrigerant. The foam-blowing agent HFC-134a/HFC-245fa is changed to cyclopentane while a mixture of propane (HC-290) and isobutane (HC-600a) is proposed in place of HFC-134a refrigerant. The proposed technologies are non-GHG technologies, which will reduce the GHG emissions. An attempt is also made to look into the interrelationship between the Montreal and Kyoto protocols, as they are supplementary to each other.

Sector and technology background

Commercial refrigeration equipment sector is one of the fastest growing sectors in India. The commercial refrigeration equipment is predominantly used in large institutions and retail outlets serving the dairy, ice cream, beverage, bakery, and frozen food industry. Basically, these appliances are used to avoid spoilage of food products, which is an important and growing concern in developing countries.

Unlike the domestic refrigerator segment, the commercial refrigeration segment has a large number of small and medium size manufacturers. These manufacturers have either changed the foam-blowing agent from CFC-11 to HCFC-141b and refrigerant from CFC-12 to HFC-134a or they are in the process of changeover. It is expected that by the end of 2002 all manufacturing of such appliances will be based on HCFC-141b as foam-blowing agent and HFC-134a as refrigerant. HCFC-141b has been adopted by the Protocol as an interim step towards fully ODS-free system. Moreover,

HCFC-141b will be phased out in the beginning of 2003 by most of the developed (HCFC-141b manufacturing) countries. The zero ODP solutions for foam-blowing agents of the HFC family are HFC-134a, HFC-245fa and HFC-365mfc. The HFC-245fa and HFC-365mfc are not yet commercially available and it is difficult to predict their availability.

It is likely that all developed and developing countries will move to HFC-134a as foam-blowing agent for commercial refrigeration.

The Montreal and Kyoto protocols

Both the Montreal and the Kyoto protocols address the environmental issues. The Montreal Protocol on substances that deplete the ozone layer was established to phase out the consumption and production of ODS within a specified time-frame both for developed and developing countries; reviewed time-to-time based on the advice from scientific, technology, and economic assessment panels. A Multilateral Fund was established by the Montreal Protocol to provide aid to developing countries in terms of technology transfer and incremental costs for implementing non-ODS technologies (Art. 5(1)). The Montreal Protocol does not address non-ODS issues.

The Kyoto Protocol has decided to club HFCs together with five other gases such as CO₂, N₂O, CH₄, PFCs, and SF₆ in one basket of controlled substances. Although CFCs and HCFCs contribute to global warming, the Kyoto Protocol does not address these substances, since these are already controlled under the Montreal Protocol with specific phase-out regimes. The Kyoto Protocol aims at the reduction and control of GHG emissions and has obligations only for developed (Annex 1) countries. While developing countries have no such commitments.

Interrelationship of the Montreal and Kyoto protocols

The issues of ozone depletion and climate change are scientifically and technically interconnected through physical and chemical processes in the atmosphere. Changes in ozone affect the earth's climate and changes in climate and meteorological condition affect the ozone layer. Because ODS are also GHGs, the ODS phase-out helps to protect the climate. The Montreal and Kyoto protocols are

interconnected because HFCs, which are alternatives to the ODS, have been included in the basket of GHGs of the Kyoto Protocol due to their high GWP.

The Montreal Protocol adopted HFCs as viable alternatives primarily because of their zero ODP and very similar thermodynamic and thermophysical characteristics as those of CFCs, HCFCs, and other ODS used in different applications. This process helps the Montreal Protocol in early phase-out of ODS cost-effectively. However, the adoption of HFCs is not a long-term and sustainable solution especially due to their high GWP. The industry is still looking for better options that is acceptable to both protocols. Natural fluids especially HC technologies can provide a long-term and sustainable alternative solutions for domestic refrigeration and small capacity stand-alone commercial refrigeration appliances.

Non-GHG technology for commercial refrigeration under CDM

Hydrocarbons having zero ODP and negligible GWP are preferred by both the Montreal and Kyoto protocols. The HC technology has been successfully implemented by many European countries and hence is a well established technology for domestic and stand-alone commercial refrigeration. This technology is a long-term sustainable solution especially for developing countries.

This case study aims to develop a proposal for use of HC technology for small capacity commercial refrigeration appliances. It considers cyclopentane as a replacement for HFC-134a/HFC-245fa foam-blowing agent and a mixture of HC-290 and HC-600 as a replacement for HFC-134a refrigerant. The CO₂ abatement and CER have been estimated using total equivalent warming impact approach.

Calculations of CERs

For the estimation of CERs, the following aspects have been taken into consideration.

Baseline

By 2002, manufacturers of commercial refrigeration appliances in India will be using HFC-134a as refrigerant and HCFC-141b as foam-blowing agent. The use of HCFC-141b is an interim step. Availability of HCFC-141b will be reduced due to phase-out plans for HCFCs in developed countries.

Therefore, manufacturers of commercial refrigeration appliances may like to switch over to HFC-134a, the only commercially available HFC, as foam-blowing agent. Thus, HFC-134a is considered as the baseline technology for both refrigerant and foam-blowing agent. The CERs have been calculated as the GHG abated by the avoidance of using HFC-134a as refrigerant and foam-blowing agent.

Project life

Project life is considered as 10 years from 2003 to 2012 although, most of the appliances will remain in service beyond 2012. It is assumed that implementation of non-GHG (HC) technologies in this sector will commence from 2003 as per the Indian regulation due to reduced availability of HCFC-141b, while 2012 marks the end of the first commitment in Kyoto Protocol for Annex 1 countries and hence marks the end of project life.

Production of appliances

A medium-size commercial refrigeration enterprise manufactures a variety of appliances. A total production of 20 000 units is considered for a medium-size enterprise in 2003 and its full capacity of production of 50 000 units/year by 2006 and onwards.

Refrigerant charge

Refrigerant charge varies from 290 g to 700 g per unit depending on the size and type of appliance. An average of 400 g charge per unit has been assumed including the losses during charging. The amount of refrigerant required for servicing of appliance during its lifetime has also been estimated by taking into account the recharge per appliance in its (10 years) lifetime.

Foam-blowing agent

For HFC-134a, a consumption of 1.85 kg per unit of foam-blowing agent has been taken based on industry data.

Recovery and recycling of refrigerant

Recovery and recycling of refrigerant as well as foam-blowing agent have not been considered in this study as this is not practised in India for such small capacity appliances.

Power consumption

Since the power consumption for appliances vary, an average consumption of 4.37 kWh per day has been taken for this case study.

Energy-efficiency

A two per cent increase in energy efficiency is assumed due to conversion of foam-blowing agent from baseline technology HFC-134a to cyclopentane. The same energy-efficiency is assumed for both the baseline HFC-134a and the proposed mixture of HC-290/HC-600a refrigerant.

Carbon credits

The carbon credit is based on the assumption that an international carbon credit market will develop from 2001 onwards. The current cost is taken as 4 dollars per tonne of CO₂ equivalent abated and is depreciated by taking a discount rate of eight per cent per year.

Results and discussions

Based on the model developed, CERs have been computed for a medium-size enterprise. The study is performed for HFC-134a abatement using cyclopentane as the foam-blowing agent and a mixture of HC-290/HC-600a as refrigerant.

Table 2 shows the amount of CO₂ equivalent abated and CERs generated due to conversion from HFC-134a to non-GHG technologies for both foam-blowing agent and refrigerant.

The results of this study indicate that there is a great potential to reduce GHG emissions by converting from HFCs to non-GHG technologies in this sub-sector.

Project additionality

The case study undertaken for conversion of foam-blowing agent and refrigerant from HFC to non-GHG technologies satisfies the additionality criteria as discussed below.

Technological additionality

The HC technology having zero ODP and negligible GWP is the latest and the best available technology for stand-alone commercial refrigeration appliances.

Table 2 GHGs (Greenhouse gases) abatement and CERs (certified emission reductions) generated due to conversion of refrigerant and foam-blowing agent

GHG technologies	Non-GHG technologies	Total equivalent CO ₂ abated (million tonnes CO ₂ equivalent)	Total CERs (million dollars)
Foam-blowing agent	Foam-blowing agent		
HFC-134a	Cyclopentane	1.08	2.69
Refrigerant	Refrigerant		
HFC-134a	HC-290/HC-600a	0.18	0.49
Foam + Refrigerant	Foam + Refrigerant		
HFC-134a	Non-GHG technology	1.26	3.18

Investment additionality

The proposed HC technology requires higher initial investment due to safety consideration during manufacturing. The additional initial investment costs are not covered by the cost-effectiveness criteria fixed by the Multilateral Fund of the Montreal Protocol and thus, HC technologies are not being implemented in this sub sector. The Multilateral Fund adopted interim solutions especially in case of foam-blowing agent and funded the projects with HCFC-141b as the foam-blowing agent.

As per provisions of the Kyoto Protocol, investment has to be additional to Multilateral, GEF or other similar funding agencies. Hence, there is a need of an additional investment to support such projects based on non-GHG technologies. The HC technology thus fulfils the investment/financial additonality criterion, since it would not be possible otherwise to implement.

Sustainability of project

The HC technology for commercial refrigeration sub-sector satisfies the sustainability criteria as discussed below.

Economic sustainability

Non-GHG (HC) technology can use indigenous resources (HC-290/HC-600a, cyclopentane, mineral oils etc.) with minimum imports. Thus this technology will result in saving of foreign exchange and also reduction of cost of the product.

Environmental sustainability

The HC technology provides excellent environmental benefits since it has zero ODP and negligible GWP. It achieves the phase-out of ODS as well as the abatement of GHG (HFC-134a). This will provide appliances that are eco-friendly.

Technical sustainability

The HC-based refrigeration appliances require only minor changes in the electrical components due to safety consideration. There are no IPR issues involved in this technology.

Social sustainability

The servicing of HC-based appliances is similar to that of ODS-based appliances with some safety consideration owing to flammability of HCs. The employment of servicing persons does not get disturbed.

Conclusion

The HC technology provides a long-term sustainable solution for both foam-blowing agent and refrigerant for domestic and small capacity commercial refrigeration appliances. The technology has zero ODP and negligible GWP, and so it is possible to achieve phase-out of ODS and abatement of GHG (HFC-134a). The technology is sustainable as HC can be made available from indigenous resources. There are no IPR issues involved for HC technology. However, HC requires safety regulations both in manufacturing of appliances and their use. This requires additional initial investment to meet the safety costs. These costs could not be accommodated in the Montreal Protocol. It thus fulfils the requirement of additionality criteria of CDM under the Kyoto Protocol. From this case study, it is evident that significant amount of CERs will be generated which will enable emissions trading.

The results of this CDM case study reveal that the project conversion of HFC technology to HC technology fulfils all the CDM criteria of the Kyoto Protocol such as sustainability, additionality, and cost-effectiveness. It is possible to generate significant CERs to adopt non-GHG technologies in non-Annex 1 countries.

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Rationale

The two competing technologies for phasing out the use of CFC-12 refrigerant in domestic refrigerators are HFC-134a and isobutane (R600a). These are currently under development in non-Annex 1 countries under the Montreal Protocol. HFC-134a is a GHG with a GWP value of 1300. The GWP of isobutane is negligible at 4. The isobutane technology was developed in Germany and leads the energy-efficient refrigerator models in the European, North African, and Chinese markets. As several Annex 1 countries are evaluating HFC emission control measures as part of the compliance strategies within the Kyoto Protocol, it seems appropriate to adopt HFC alternatives where such alternatives are available at comparatively low incremental cost. Isobutane technology in domestic refrigeration is such an alternative, particularly since it offers the potential to improve the energy-efficiency significantly. Energy-efficient designs have been incorporated in isobutane refrigerators along with the improving safety-related aspects. This has resulted in a high share in the energy-efficiency class of the European Union's labelling scheme. Though the application of HFC-134a as refrigerant allows the continued use of CFC-12 designs, it needs more care in selection of materials and with moisture control during the manufacturing process.

The combination of HFC-134a conversion to isobutane along with energy improvements in the designs of domestic refrigerators has received increased attention under the climate programme of the GEF (Global Environment Facility).

Description of the project

In India, the case of the 165-litre model popular refrigerator has been investigated as a possible CDM project for a model manufacturer entering into a technology cooperation with

an Annex 1 HC technology partner. The annual sales by the manufacturer are assumed to be 800 000 units. All smaller refrigerators sold on the Indian market show basically the same layout of the refrigeration system. A brief summary of the case study focusing on HFC abatement through conversion to isobutane refrigerant is appended as case study 1.

The basic design of the Indian 165-litre refrigerator dates some 20 years back and demands overhaul from an energy consumption viewpoint. Power consumption varies from 0.75 to 1.5 kWh per day. The limit set by the Indian standard is 1.25 kWh per day for a 165-litre refrigerator. For this case study, a baseline power consumption of 1.1 kWh per day is assumed for the 165-litre refrigerator.

The charge quantity of CFC-12 per unit is 100 g (HFC-134a: 95 g) to which 20% handling losses are to be added. The manufacturers interviewed have been evaluating the merits and demerits of both the HC and the HFC-134a technology and, as a result, intend to convert models with direct cooling to isobutane. One manufacturer interviewed has an approved Multilateral Fund conversion project based on HFC-134a, the second got a project based on isobutane refrigerant approved in the 30th meeting of the Executive Committee in March 2000. While the Multilateral Fund provides for incremental cost in conversion of the production facilities, it does not fund the cost involved in developing new model designs that are safe and more energy-efficient. With the HFC-134a option, the necessary design changes required would be quite less as the same tools used for production of CFC-12 models can be used for the HFC-134a model. With HC refrigerant R600a, some design changes would be necessary to address safety issues, with a little extra cost, as number of production tools have to be changed. The Chinese manufacturer Kelon produces a 165-litre two-temperature R600a HC refrigerator with a more advanced design. Its energy consumption is 0.95 kWh per day. The power consumption of the Indian 165-litre baseline model is 1.10 kWh per day or up to 15% above the mark of a comparable model designed as per the next generation R600a technology. For the purpose of this case study, we assume that by redesigning evaporator layout (to match R600a safety standards), eliminating thermal bridges, and by using a R600a compressor with an updated design, the energy consumption of an Indian

165-litre refrigerator can be cost-effectively reduced by 10%. It is assumed that this energy-efficiency package is adopted step-by-step across the range of models, that will give a three per cent overall energy-efficiency improvement in 2003.

Baseline

The investigated case suggests that we apply a combination between a project-specific baseline along with technology benchmarks to demonstrate environmental additionality and potential GHG emission reductions. The proposed project duration is seven years from 2003 to 2009. As of 1 January 2003, the Government of India has announced ban in the use of CFCs in new appliances. Based on projects approved by the Multilateral Fund, the Indian domestic refrigerator market would largely be converted to HFC-134a by this date. Enterprises taking an initiative by introducing HC refrigerators of higher energy-efficiency at this point can claim environmental additionality at least for the period (assumed seven years) until the majority of the market adopts this more environment-friendly technology. Limiting the project duration to seven years appears to be a plausible assumption during which the reduced power consumption of the refrigerators in the market is likely to sustain. The energy-efficiency of refrigerators is uncertain after service. After seven years of use the chances of service increase under Indian power grid conditions.

Monitoring and verification

For demand-side projects, such as energy-efficient refrigerators, an independent certification of the energy consumption of a given set of models needs to be established at the country-level. The aggregate carbon offsets achieved by the project, however, are not based on the single refrigerator but on the entire production and in meeting the certified GHG emission criteria in production and use. Monitoring of production numbers may be established in India through the excise duty administration.

GHG abatement and unit abatement cost

Under the investigated scenario, out of 2.17 million tonnes of CO₂ equivalent abated, 1.21 million tonnes of CO₂ equivalent result from energy-efficiency improvements during the first seven years of operation. This duration is reduced by

the refrigerators produced in 2009 to three years, as no carbon offsets materializing later than 2012 are considered. From replacing the refrigerant from HFC-134a to isobutane, equivalent emissions of 0.94 million tonnes of CO₂ are abated, which are only 43% of the total. This underscores the importance of energy-efficiency improvement as potential CDM cases. The project cost is estimated at 6.21 million dollars, excluding the contribution by the Multilateral Fund of the Montreal Protocol abatement cost of 2.9 dollars/tonne of CO₂ equivalent (Table 3). The net return per unit of CER to the investor after a discount rate of eight per cent a year has to reach 4 dollars/tonne of CO₂ to make this project economically viable.

Table 3 Energy-efficient hydrocarbon refrigerator case: baseline and greenhouse gases abatement cost

	<i>HFC-134a</i>	<i>R600a</i>
Refrigerant emissions		
Annual production of 165-litre model	800 000	800 000
Refrigerant per unit (g)	115	44
Refrigerant consumption per year (million tonnes/year)	92	35
Global warming potential (tonnes of CO ₂ equivalent/tonne)	1300	16
Equivalent emissions (CO ₂ /year) (tonnes of CO ₂ equivalent/year)	118 000	150
Cumulative CO ₂ emissions during project lifespan of seven years (tonnes of CO ₂ equivalent)	949 000	200
Power consumption of refrigerators during first seven years of operation		
Assumed number of refrigerators under this project in seven years	6 350 000	6 350 000
Power consumption per refrigerator/day (kWh/d)	1.10	0.99
Emission factor Indian grid power (including 30% transmission losses) g CO ₂ /kWh	1.16	—
CO ₂ emission reductions from power consumption (tonnes of CO ₂ /year)	71 000– 250 000	—
CO ₂ emissions reductions during first seven years of operation of fielded refrigerators, in maximum up to 2012 (tonnes of CO ₂)	1 221 000	—
Total equivalent CO ₂ emission reduction under project (tonnes of CO ₂)	2 170 000	—
Estimated project cost (dollars)	—	6 210 000
GHG abatement cost (dollars/tonnes of CO ₂)	—	2.9

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Introduction

This case study addresses the upgradation of a cluster of small-scale foundry units in Howrah, near Calcutta, in India. The use of advanced divided-blast cupola technology with high-efficiency pollution-control systems could lead to large reductions in CO₂ emissions, as well as to improvement in local air quality. The adoption of this technology is constrained by its initial high cost, and the lack of a credit and technology delivery system. The CDM project would piggy-back on a commercial credit line, and CDM funds would finance the establishment of a delivery mechanism and an interest buy-down to raise the return on investment to an acceptable level.

Rationale

The mass production of iron castings started in India in the 19th century. Today, there are about 7000 foundries in the country with an installed capacity of 3.5 MT (million tonnes), but production hovers around 2.5 MT. These units are mostly located in clusters, with the cluster size varying from less than 100 to around 400 units. The energy intensity of these units is quite high, and presents an ideal situation where both energy savings and pollution reduction can be achieved through technological upgradation.

The Howrah belt of West Bengal has one of the oldest and the biggest cast iron foundry centres in the country. Of the 0.8 MT of grey iron castings produced per year in West Bengal, the Howrah cluster accounts for 0.5 MTPA (MT per annum), which is 20% of the total castings produced in the country. Technological packages for upgradation is also constrained by the lack of professional manpower in these units. The export of castings from foundries in West Bengal is about 0.25 MTPA, valued at almost 25 billion rupees, and

substantial growth in exports is possible. The Howrah cluster is the biggest exporter of castings in the country and is located near the port. A few units have also acquired ISO 9000 certification. The cluster has a concentration of about 550 foundries within an area of 1467 square kilometres. Another 20–30 foundries are located at the periphery of the main cluster.

A majority of foundries operating in Howrah cluster are managed by entrepreneurs and operated by persons who acquire skill through hands-on experience in the plant. The availability of skilled labour is dwindling. With increasing costs of production in the foundry, the resultant low-value-added castings do not bring in enough profit to enable the entrepreneur to invest in modernization and upgradation. At the same time, access to the adoption of appropriate credit is difficult because of the relatively high transaction costs of the process for these units.

Project objective

The project involves establishing delivery chains for credit and technology to the small-scale foundry units. The process would enable the introduction of a new technology using a divided blast cupola with a matching pollution control system. This new technology is proven in the Indian context but not commercialized as yet.

Despite the development, demonstration, and acceptance of this technology, its adoption within and beyond the Howrah cluster faces technical, financial, and institutional constraints related to the limited capacity of the units to absorb technology and access credit. The overall purpose of the CDM project is to decrease transaction costs to users, and thus increase the financial attractiveness of the energy-efficient and environmentally sound technology for its wider adoption at small-scale foundries cluster at Howrah.

Project baseline

Most of the foundries operating in the Howrah cluster have a small scale of operation. The furnace size typically varies in the range of 61–137 cm in internal diameter. All of the foundry units use coke as fuel, which has a very low carbon content due to its inferior quality. Any international average baseline is not applicable in the project case, as no international

comparison is valid given the typical fuel used with its quality and the scale of operation of the units in the Indian foundries.

The lack of operating records of the small-scale units and the high transaction costs involved in generating this data imply that a baseline centred on national or regional average would not be practical. The most pragmatic option is a baseline established on new units being installed currently. A few such marginal additions could be easily monitored. The baseline for this project case would, therefore, be the last plant set up in the cluster with a conventional cupola technology and with a local pollution control system to meet the stipulated emission standards.

Project costs and benefits

The results of the demonstration plant in Howrah show that the technology is 33% more energy-efficient than the best foundry unit in the cluster and 65% better than the worst case. This translates to a huge potential for coke saving as well as CO₂ abatement. The basic field data for both the baseline as well as the project cases are compared in Table 4.

Table 4 Basic data for the foundry project intervention

Parameter	Baseline case	Project case
Coke consumption (1000 tonnes/year)	218.4	132.6
Coke melt ratio (%)	18	9.2
Suspended particulate matter emission (mg/Nm ³)	557	53
CO ₂ emission (1000 tonnes/year)	523.4	336.3

The capital cost of the project would be about 1.2 billion rupees (28.6 million dollars). It targets CO₂ as the major GHG for mitigation. The present CO₂ emissions from the sector are about 523.4 kilotonnes per annum. Assuming the participation of 300 units in the project and taking a 10 years period from 2002 to 2012 for CERs, the reduction of CO₂ emissions works out to about 187.2 kilotonnes per annum (a 35.8% reduction) by the intervention. The cost-effectiveness of the intervention works out to be 24.17 dollars per tonne of CO₂ abated. The results of the financial analysis of the project are shown in the Table 5.

Table 5 Financial returns of the foundry project intervention

Parameter	<i>Baseline case</i>	<i>Project case</i>
Net present value	Negative	Positive
Internal rate of return (%)	17.7	28.0
Payback period (years)	>15	3

The CDM project would fund the establishment of a technology and credit delivery mechanism, which will cost about 3.75 million dollars over a five-year period, after which this mechanism is expected to become financially self-sustaining. This mechanism would also monitor CO₂ emissions abatement. Apart from this mechanism, the CDM funding for the interest rate buy-down would also be required in order to achieve an attractive rate of return on investment for the entrepreneurs. This interest rate buy-down is expected to total to about 1.1 million dollars. This could be piggybacked on a commercial credit line of about 22 million dollars.

Project additionality

The project will help in setting up and capacity-building of technical and financial intermediaries. As a result of the successful implementation of this project, intermediaries for providing local technology support, technology performance assurance, day-to-day trouble-shooting, and further research, design, and development for continuous technology improvement could be acquired with their enhanced skills. The project is also expected to pave the way for the development of special financing packages suitable for small-scale industries by domestic financial institutions.

Sustainability

The project is compatible with national priorities and contributes to sustainable development of the country. It would result in increased growth of small-scale industrial units with the efficient use of energy and raw material (natural resources). Better product quality may see increased value of production, exports, and foreign exchange earnings. The project would also result in increased employment due to increased foundry operations. One of the greatest advantages

of the project is significant reduction of particulate emissions, which is the major pollutant from a foundry unit.

Monitoring and verification

After the process of official approval by the respective governments of the host and the investing parties, the project is ready for implementation. During the operational phase of the project, its performance in terms of actual emissions reduction must be monitored. The individual unit management, assisted by the technical intermediaries and the local cluster association would generally carry out monitoring. Monitoring for this project could be based either on the fuel (coke) consumption, end-use energy-environmental performance, or operating efficiency (coke to melt ratio) of the melting furnace (cupola).

The actual emission reductions achieved by the project must be verified by an independent operational entity by auditing the records maintained by the unit and the technical intermediaries. One of the local auditing firms could well act for the verifying agency. This agency would be responsible for auditing and verifying the 'additional' emissions reductions that could then qualify for certification. Based on the report of the verifying agency, the final certificates of emissions reductions would be issued by the UNFCCC Secretariat.

Conclusion

The foundry project seeks to upgrade the technology in a sector where it is not happening on its own. This type of CDM project would enjoy the advantage of higher productivity in established markets and would be sustainable once the initial transaction and learning (risk management) costs have been overcome. The CDM benefits would help in market development and in meeting technological risks associated with the introduction of these technologies. The current technology being chosen to meet the same requirements would be the baseline technology, and the performance of the marginal plant added would set the performance baseline.

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Objectives and scope

This study aims to develop a simulation case of advanced cogeneration in sugar mills, under the CDM of the Kyoto Protocol. A project model has been developed to estimate equivalent carbon offsets arising due to implementation of advanced cogeneration power project in an Indian sugar mill, on BOOT (build, own, operate, and transfer) project principles. The study also looks at the replicability potential of such projects in Indian sugar mills.

Sector background and justification

Sugar industry in India has been well-established since 1930. As of today, 440 sugar mills are in operation in nine sugarcane-producing states across the country. India is the largest producer of sugar in the world and the sugar consumption per capita is quite high, compared to the world average. Sugar mills in India are located in mofussil parts of the country, near the cane fields. They have largely contributed in the rural development and they virtually act as centres for rural and sustainable development.

The Indian sugar industry today has critical economic status due to national and international market and policy framework. This has resulted in their limited access to resources and capabilities. Their energy needs have increased over the years due to expansion and diversification. They offer excellent potential for modernization and energy-efficiency improvement. Sugar mills cogenerate steam and power for their own requirements during season, by burning renewable fuel generated in the process, i.e. mill bagasse. The technology configurations for this captive cogeneration are still inefficient, leading to inefficient utilization of bagasse.

Usage of extra high pressure and temperature configuration for advanced cogenerating steam and power in sugar

mills has excellent potential of generation of exportable surplus, over and above the captive requirements. This sector has a potential of generating exportable surplus from such projects to the tune of 4000 MW. In spite of this potential, the actual implementation till date is a mere 175 MW. This of course is due to borderline economic viability of these projects, for prevailing power purchase and lending rates and complex barriers related to technology, finance, policy, regulation, and development. These projects are an excellent sustainable option for integration and for improving performance of the Indian sugar mills.

Advanced cogeneration projects in sugar mills are environmentally benign and also provide benefits of decentralized power generation. They offer sustainable benefits like improvement in rural economy, employment opportunities for rural populace, and improvement in quality and availability of power in the rural grid.

These projects are now a national priority and substantial promotional and policy support is available through the MNES (Ministry of Non-conventional Energy Sources). These projects also offer emission reduction due to displacement of fossil-fuel-based utility generation, improved energy-efficiency and optimum utilization of the same quantum of renewable fuel. These projects are ideally suited for the CDM process in meeting the demands of the Kyoto Protocol.

Project background and economics

An Indian project developer has been working on this project at a host sugar mill on BOOT principles. The proposed project will be built adjacent to the host sugar mill complex. A project development agreement has been signed between the project developer and the host sugar mill for committed transactions across the fence, over the BOOT period of 20 years.

Under this agreement, the host sugar mill will transfer all the mill bagasse to the project developer free of cost. It will also provide him required land / access road / construction power free of cost; water for operation of the cogen plant; provide uncontaminated condensate; and dispose of the treated effluent and ash from the cogen plant in its existing effluent streams. The project developer, in turn, will provide required quantities of steam and power to the host sugar mill

for its in-season and off-season operations and also will provide incentive per unit of power sold to the SEB (state electricity board) grid.

The proposed cogen plant will employ the latest technology and equipment with extra high pressure configuration, equal or even greater than 60 kg/cm². The project capital cost also envisages specific equipment for host mill modernization and energy-efficiency improvement, over and above all the equipment and facilities required for the proposed power plant. The project developer will sell optimum quantum of exportable surplus to the SEB or third party, under a bankable power purchase agreement for 20 years of the BOOT period, to generate its own revenue. The present power purchase policy announced by various SEBs is 5.2 cents/kWh at base year 1994/95 and a five per cent increase every year. The design of the power plant ensures optimum usage of mill bagasse during the season of 180–200 days, procured bagasse / local biomass for about 90–120 days during off-season and small quantities of fossil fuel, if required, for balance period to generate optimum exportable surplus, on year round basis.

For a typical mill capacity of 5000 tonnes of cane/day, crushing 1.1 million tonne sugar cane every year and generating 31% mill bagasse, the installed and exportable surplus capacities of the project will be respectively 30 MW and 22 MW. The project will export 160 million kWh/year on biomass fuel for 300 days operation, after meeting all the captive requirements of steam and power.

The major parameters of financial analysis of this project are given below, for both the options, i.e. with or without available incentives from the MNES. Table 6 gives comparison of these parameters, with the desired viability norms by the project promoters.

It is seen from the above table that the project is just on the borderline of financial viability, considering that the incentives are available only for few demonstration projects. The borderline viability indicators have been worked out at the prevailing prices of equipment, lending rates of Indian financial institutions, and purchase price for exportable power. Any increase in the purchase rates from the SEBs or decrease in the lending rates is unlikely to take place, in view of the complex energy pricing and the economic situation. Hence, borderline economic viability status of such projects will continue in future.

Table 6 Comparison of parameters with the desired viability norms

Parameter	Value		Desired viability parameters
	Without incentives	With incentives	
Capital cost/MW (Rs million)	30-45	30-45	30-45
Average DSCR	1.6-1.8	1.8-2.0	2.1-2.3
Payback period (years)	7-8	6-7	4-6
Internal rate of return (post-tax on equity) (%)	16-20	22-25	35-45

Apart from borderline viability, complex barriers still exist. This has resulted in very low pace of implementing such projects. The borderline viability and barriers do not offer enough incentive for the sugar mill owners or even the project developers to take firm decisions and implement them in the immediate future. The major financial risk of delayed or non-payment from SEBs, who themselves have poor financial health, also retard their decision-making process. The seed money that can be made available to developers of such projects, for CO₂ emission credits under the CDM of the Kyoto Protocol, will bring them under the desired viability norms indicated above. This will help quicken the decision-making process of the project developers.

Clean development mechanism

Of the three flexibility mechanisms under the Kyoto Protocol, CDM provides an opportunity for non-Annex 1 parties to gain access to internationally accepted non-GHG technologies and investment from Annex 1 countries, while the Annex 1 countries get CERs for meeting their emission reduction commitments. The basic principles of the CDM are to provide an opportunity for realizing real and measurable carbon emission reductions, to meet the sustainability development criteria for the developing countries. In view of the national priority, sustainability development criteria and associated emission reductions, the captioned project(s) perfectly qualify for CDM criteria under the Kyoto Protocol, so as to claim the incentive / seed money from CERs sold in the international carbon offset market. This also brings the

project(s) within the desired viability norms and helps cover the financial and barrier risks as well.

Baseline and additionality criteria

The main baseline for this project will be the benchmark CO₂ emission intensity of 0.812 kg/kWh for power, replaced in the national average power mix. The baseline of national average power mix is well justified, since any new major power project getting commissioned will be primarily thermal power, based on fossil fuels including coal, natural gas, oil, or naphtha. Hence, the national average power mix is not expected to get disturbed drastically in the near future. There is an option to update this sector benchmark every five years. This intensity is derived from the emission factor for the national power mix in India (70% coal and thermal-based power).

The project-specific parameters of the prevailing situation today are indicated below.

- Boiler/Turbine generator pressure configuration of 32–42 kg/cm², achieved commercially so far with incidental co-generation
- Steam-driven mills
- Poor host sugar mill energy efficiency, 50% steam consumption on cane and 20 kW/tonnes of cane crushed per hour power consumption
- Poor instrumentation and control
- Poor/average skills
- Average suspended particulate matter emission level of 1500 mg/Nm³
- Conventional/low technology equipment for emission control
- Existing CO₂ emissions
- Poor quality, availability, and reliability of grid power, locally
- Existing poor socio-economic status.

Compared to this prevailing situation of cogeneration in sugar mills, the proposed project under CDM established the following additionality criteria.

- Latest technology with extra high pressure boilers / turbine generator of 60 kg/cm² and above leading to improved power output, reduced energy consumption, reduced operating cost, improved instrumentation and control, improved quality of grid power, etc.

[illegible]

financial viability indicators also shift towards the desired viability parameters indicated in the project economics earlier. This seed money available through the CDM process will make the project developer decide on the proposed project.

Sustainability development

The proposed project offers the following contributions to sustainable development.

- Skill upgradeability
- Local employment potential (200 direct and 1000 indirect per project)
- Additional income for farmers (Rs 100–150/tonne of cane) and local populace
- High / Efficient resource utilization, mill bagasse / procured bagasse / local biomass
- Energy-efficiency improvement and cost reduction, improved viability of the host sugar mill
- Improved quality, availability, and reliability of power in the vicinity
- Improved business culture in the host sugar mill
- Improved social amenities like schools / hospitals / temples around the host sugar mill location
- Maximization of power generation per tonne of biomass fuel
- Offsetting of large foreign direct investment for centralized thermal power plants.

Monitoring, verification, and certification

- Intensity of emission reduction
- 0.812 kg CO₂/kWh of exportable power for the displaced capacity of new fossil-fuel-based thermal power plant to be updated periodically
- Reduction of 0.3 tonne of particulate matter per tonne of cane crushed
- Exportable power, being source of revenue for the project, will be accurately metered and monitored
- Reliable computation of CO₂ offsets and emissions of the project(s) based on exportable power, fuel mix used, and applicable intensity factor for emission reduction
- Easy verification of CO₂ credits over the project life-time, even for any future changes in intensity due to changes in the baseline

- Adequate certification for CO₂ credits over the project life, as competent/authorized certification agencies will come in place.

Conclusions

The proposed project qualifies both for sustainability development and emission reduction criteria under the CDM of the Kyoto Protocol.

The seed money that can be made available for the project(s) under CDM is certainly quite attractive for the project developer(s) and will help reduce the Indian debt ratio to that extent. This certainly brings the economic viability parameters of the proposed project(s) within the desirable range. The developer(s) of the proposed project(s) will certainly get motivated to decide on the implementation immediately.

In view of scarcity of funds with the sugar mills as well as the project developers in the Indian context, the role of international investors will play a very vital role in replicating such projects under the CDM. The excellent replicability potential of this sector can be effectively implemented and the existing financial barriers can be overcome.

Thus, the CDM can help this sector to implement the captioned project at a much faster pace, compared to the sluggish growth and such projects will get multiplied all over the country.

